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CDIO BASED COURSES IN ENGINEERING BIOLOGY AT LINKÖPING UNIVERSITY

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ABSTRACT

CDIO based courses have traditionally been implemented into education programs with predominatly mechanical, aeronautics and electrical/physical content. However, improved engineering skills are needed also in other engineering study programs, such as those emerging in biotechnology. The previously developed CDIO-courses (themes) at Linköping University, that are primarily intended for the Applied Physics and Electrical Engineering program, constitute today the platform also to these other study programs at the university.

The bioengineering program named "Engineering Biology" at Linköping University, Sweden, with focusing on bioprocessing, biomaterials, molecular biotechnology and technical biomedicine, introduced recently a CDIO-project course during the second semester of the first study year. The intention is now to continue with a similar program development also during the 3rd and 4th study years; prior to the diploma (i.e master) thesis work and we hope this traditionally science oriented program in due time will be pervaded by the CDIO engineering approach. The contents in the first year five weeks full time project is a combination of traditional engineering exercise and modern biology/chemistry with strong emphasis on biotechnology and chemical engineering. Each student group is up to seven participants, and the newly developed projects include themes such as synthesis of nanoparticles with concomitant testing in a sensor application, acquisition and analysis of bioelectrical signals from the turtle heart, and visualization of differently colored culture or tissue cells.

The teaching staff is mixed with members from both the technical and medical faculties. As this is the first time the combination staff be used all teachers are unexperienced in this type of collaborative work. Therefore, internal education (course in the LIPS model) has been offered prior to course start to all personell.

KEYWORDS:

CDIO, DBT course, bioengineering, engineering education, project course

INTRODUCTION

The course and teaching tradition in electrical, mechanical and aeronautics engineering programs has always been project oriented with emphasis on problem solving by mathematical, computing and other engineering tools even though there is today a need to reinforce the engineering aspects. In the new engineering field of bioengineering different traditions from science and medical educations must be combined into the need of engineering. There is an obvious risk that students from these engineering programs will be looked upon as students from programs without engineering skills and mistakingly be excluded from engineering positions.

The management board of the study program "Engineering Biology" decided to examine the CDIO Inititive [1] closer and especially the developments made within the Applied Physics and Electrical Engineering Program at Linköpings University. The Applied Physics and Electrical Engineering Program has since its start in 2000 been one of the early collaborators in the CDIO Initiative. This is also the reason to why the Engineering Biology board has chosen to adapt some of the CDIO concepts in their study program. To the best of our knowledge, this bioengineering oriented program is the first of its kind to adapt the CDIO syllabus.

THE CDIO INITIATIVE

The CDIO Initiative was started in 2000 with four participating universities in Sweden and USA. During the project other universities has jumped on the wagon and a list of the participants can now be found via the CDIO web site. The CDIO syllabus [2] and the CDIO Standards [3] are two basic documents for the development of the engineering programs. .

ENGINEERING BIOLOGY PROGRAM

The Engineering Biology Program was developed and set up during 1992-1993 and the first group of students was admitted in fall 1994. In the very start we admitted 30 students annually but since 1999 this number was raised to 60 students per annum. The course content and specializations during the 8th semester (profiles) are shown in Figure 1. The nominal study time is 4.5 years, corresponding to 180 units, i.e 40 units/year. Each unit corresponds to one week full-time workload.

Engineering Biology

YEAR 1

- Animal Diversity 3 p
- General Chemistry 4p
- Algebra 4,5 p
- Physical Chemistry 5p
- Foundation Course in Mathematics 4p
- Principles of Physics 3,5 p
- **Engineering Project 4p (Introductory CDIO-course)**
- Calculus, one variable 7 p
- Introduction to Programming 5p

YEAR 2

- Engineering Mechanics 3p
- Organical Chemistry 4p
- Numerical Methods 5p
- Probability and Statistics part 2, 3
- Electrical Circuits 3p
- Probability and Statistics part 1 2,5 p
- Physics 4 p
- Calculus, several variables 6p
- Biochemistry 5p
- Cell Biology 5p

YEAR 3

- Microbiology and Immunology 6p
- Systems Physiology 4p
- Databases and Bioinformatics 4p
- Gene Technology and molecular
- Automatic Control 4p
- Analytical Chemistry 4 p
- Mesurement Technology 3,5 p
- Molecular Physics 6 p
- Signal and Image Processing 4,5 p
- **Planned DBT course 5 p**

YEAR 4

- Electives total 20 p
- Profiles
  - **Bioinformatics**
  - **Bioprocess Engineering**
  - **Bioengineering Physics**
  - **Microbial Biotechnology**
  - **Protein Chemistry with Protein**
  - **Biomedical Engineering**

YEAR 5

- Master Thesis 20 p

Bold letters show the DBT courses

Figure 1. Curriculum for the Engineering Biology Program 2005

OVERALL CDIO IMPLEMENTATION IN THE STUDY PROGRAM

The first step in the implementation of the CDIO philosophy into the program was the decision to develop a first-year introductory course, “Engineering Project”. The previous introductory course was largely lecture based with the aim to orient the newcoming students to the bioengineering area. As the program of Applied Physics and Electrical Engineering recently developed a similar course to their newcomers, their course was used as a template and starting point for our new course [4]. The challenge was to develop projects with elements of conceive, design, implement and operate within the classical subjects of biology and chemistry, with teachers from medical and science backgrounds.

The learning objectives in the course is to relate basic concepts in physics, chemistry and biology to practical engineering, to develop the understanding of engineering at large and how the work is performed, administration, project planning, personal communication, documentation, project management, oral/written presentation of project results and finally, to contribute to and share responsibilities as a member of a team.

The course consists of lectures related to the project type of work (i.e. organization of work), lectures related to the individuals role as engineer, and theory of the project in itself. The complete course syllabus can be found on the web site of the program (http://www.lith.liu.se/sh/civing/index.html).

The first year four projects were run within the course. Each of the four projects had a customer (professor) who defined the project technical requirements (order). A course assistant performed the teaching and assisted the students in the practical laboratory work and assisted in the solving of everyday expected/unexpected practical problems. The core student groups consisted of up to 7-8 participants per group. Students took voluntarily different rolls such as project leadership, computing, chemical/biological experiments, statistical analysis and authoring.The project leader was responsible for the final delivery to be made in due time. He/she was also the one person that negotiated with the customer regarding changes in the original order because of practical hindrances and time shortage.

All staff members involved in the projects must prior to start be educated in the project model, LIPS, a project steering model used at Linköping University. LIPS was developed especially for the DBT (Design-Build-Test) courses [5]. The students were supposed work approximately 20 hours per week during a 10-week course period. The result from the projects were presented in a written report that was delivered to the customer and gave an oral presentation on a project conference.

The next major step in the implementation of the CDIO syllabus will take place the reorganization of courses during the 4th study year. During fall 2005 the project courses in the Engineering Biology specializations (profiles) will be transformed into DBT project courses, using the project management model LIPS. This is expected to become an iterative process, which is both possible and necessary as the 4th year student groups have yet not been exposed to the CDIO Initiative. The current 4th year specialization courses will be Project in Bioinformatics, a Biomaterials Project, and a Bioprocess Engineering project. Before the start the teaching staff will, again, be requested to follow a seminar on the CDIO Initiative, and especially focus on the concepts of DBT courses. Most of the present projects contain parts of the concept but not fully in detail. For instance, the sizes of the student groups must be changed to suit the project work model. Until now the specialization project groups on the 4th year consist of maximum two students and this number must be increased. Sometimes the projects actually are parts of a bigger project and in such cases the projects can easily emerge into one larger project. To assist in this development, the teachers will be offered a LIPS course where they, in a way similar to the students course will be exposed to and develop their own course and the project tasks. Such courses will be carried out during spring semester 2006.

A forthcoming challenge for the management board of Engineering Biology is to re-design the third study year of the program. The board must decide on which course in the syllabus of the program that will be exchanged for another DBT course. Since all higher education in Sweden will be changed according to the Bologna declaration, like all european education, the board decided to wait for further governement instructions before final planning of the details.

During the planning process of the first year course it was pleasant to observe the enthusiasm and the abundance of project proposals in the bioengineering area. Below follows a short description of the current projects carried out spring 2005.

Nanoparticles for Sensing Purposes in Car and Fuel Exhaust Gases

SiC-FET sensors have been developed in the sensor centre S-SENCE during approximately 10 years, for use in hot and corrosive enviroments such as fuel exhaust gases. Today's sensors are sensitive to hydrogen, ammonia, hydrocarbons and to a certain extent carbon monoxide. Increased selectivity is, however, needed for the realization of a sensor array to be used in simultanous detection of single gas components in car- and smoke exhausts. Nanoparticles made from pure metals and metal oxides can be taylormade to assist in molecular selectivity. The chemistry department conducts since a number of years research in the area of nanoparticles, and knowlewdge exists about several particulare systems and their synthesis methods. In the present project, the nanoparticles will be synthesized and tested as sensor array materials aimed for "On Board Diagnostics" (OBD) detection. One example of OBD is a carbon dioxide sensor placed in the exhaust gas after the car exhaust catalyzer, and the information will be continuously displayed on a screen inside the car.

In the present project nanoparticles will be synthesized of titanium dioxide (TiO_2), impregnated with platinum (Pt), and finally become coated with a gas sensitive condenser layer made of silicon carbide (SiC). The particles should thereafter be mounted and their sensitivity regarding H_2, NH_3, "HC" (i.e. different hydrocarbons), CO and NO tested at 300^oC (relevant for diesel- and smoke exhausts) and at 500^oC (relevant for gasoline exhaust). The sensitivity should be compared to presently existing exhaust sensors at S-SENCE.

Acquisition and Analysis of Bioelectric Signals from Turtle Heart

The development and commercialization of new drugs by the pharmaceutical industry is strictly governed by the International Conference guideline on Harmonization on Safety Pharmacology Studies for Human Pharmaceuticals. The ICH guideline provides a framework for the core physiological systems and parameters of the cardiovascular, respiratory and central nervous systems that are to be evaluated for each new compound. Beside those listed in the ICH guideline, new parameters are constantly under consideration in order to improve the safety of newly developed pharmaceutical compounds. In 1997 the European Medicine Evaluation Agency (EMEA) issued a memorandum concerning the assessment of the potential for QT interval prolongation by non-cardiovascular products (Picard and Lacroix, 2003). Screening of alterations in the QT interval is now routinely performed by pharmaceutical companies. The QT interval is a measurement of the period from the earliest activation of ventricular cells to the completion of their recovery (repolarization) and can be obtained from standard electrocardiograms. Lengthening of the QT interval is a feature of some cardiac drugs (class III anti-arrhythmics) but also of some drugs used for the treatment of non-cardiac diseases.

Lengthening of ventricular repolarization is a serious medical problem that can lead to fatal arhythmias and sudden death. Manual measurements of the QT interval has been associated with problems of reliability and inter-observer variation (Murray et al., 1994) so automatic processing is preferred and different algorithms have been proposed (Laguna et al., 1990). The project is aimed at the design and implementation of an off-line software tool to estimate the standard cardiac interbeat (R-R) and intrabeat intervals (P-R, Q-T) that could be of potential use for the screening of QT lengthening effects of pharmaceutical compounds.

The Morphology and Cytoskeleton of Cells

Cell biology offers many exiting technical challenges to the engineer. In order to be able to safely diagnostisize and to perform advanced medical research it is in today's healthcare necessary to collect tissue- and cell samples at the clinic and analyze them at specific laboratories because many of the samplings contain cells and sub-cellular components too small for the detection by the naked eye, 0.1 mm. In addition, materials with biological origin is rapidly degraded by proteolytic activity outside its physiological milieu. This is a big problem as the intention is to preserve intact samples for a later analysis. It is therefore common pratice to chemically crosslink the biological samples when collecting them at the clinic or laboratory. This facilitates the evaluation of the cell- and tissue samples at a later stage. In addition to magnification contrast enhancement is needed for many molecules and structures. One example of the latter is the cytosceleton. A common means to contrast enhancement is the use of optical methods and more or less specific molecular markers. Sample coloration, light microscopy, photography and image processing are then common steps during the analysis. One problem is, however, that the image processing software companies often locks the software to their own standards in specific instrumentations with a defined image format. The possibility to evaluate raw data by the use of free software is desirable, especially as the instrumentation often is heavily booked. The aim of the present project is to handle clinically obtained and prefixated patient tissue- and cell samples and to optimize cytosceletal and cell morphologic optical measurement methods with improved image processing at external working stations by the use of freeware. The results will be used to find disturbances in the patients cytosceletal functions.

Weather Observation and Forecast Station at LiU.

Throughout the cumbersome history of man, different more or less successful approaches have been used to predict the next days or seasonal weather. However, we have only lately obtained science based methods to make reliable future predictions, forecasts. This is largely due to an efficient data production, collection and increased computing capacity. Weather forecasts are today extremely important in air trafficing and sea transportation, but also to other societal groups such in farming, touristing and merchandise. The yesterdays and tomorrows weather is also of interest to the ordinary citizen and is often discussed e.g. during coffee breaks and other social occasions. In order to make good predictions, reliable weather observational data need to be collected with a variety of meteorological instruments. By using these in combination with advanced computing and a proper physical model which describes the athmospheric movements, forecasts can be made for the forthcoming days. Hopefully the present predictability is better than that of a passive prediction only, saying that the weather of tomorrow is within 60% certainty like the weather of today.

The aim of the present project is to learn to collect weather observational data and to make weather forecasts based on these data. For this purpose, we have placed a number of weather observation sensors at the Physics Department roof at LiU. All data are collected in a lap top PC. By using the graphical computing language LabVIEW the sensor data can be used and translated to physical entities such as air temperature, air pressure and wind speed.

The weather forecasts and long term weather stastics will be presented in a graphically appealing and easy way. We also hope this weather station will be used as a reliable local weather forecast facility easily reachable via the Linköping University web-site.

So far the students have been very pleased with the course and the CDIO Initiative though there are some minor things to improve. One is to change the project “Weather observation and forecast station at LiU” to a project more related to biology and chemistry. The students who performed this project are a little dissapointed in the weak connection to their program.

The Engineering Biology Program is in Accordance with the CDIO Engineering Approach

The board of Engineering Biology has recently carried out a survey to alumni and will use the result in the process of redesigning the program. The result supports the effort to strengthen the engineering identity and to implement skills that was asked for [6].

Earlier smaller inquiries have been done concerning the content in the physics and the biology courses. The result from these were that the courses must get an increased element of technical application as well as the techniuqes being taught. This was especially important for the courses in biology.

All these results together with the basis from the work that has been carried out in the developing process of the Applied Physics and Electrical Engineering Program further inquiries will be done [7]. During the autumn 2005 a curriculum benchmarking will be carried out and nessecary changes executed [8].

The effort of educating teachers in the LIPS model and about CDIO will continue and one of the most important issues is that teachers in science and the teachers from the medical faculty participate in this to connect their subjects with engineering concept.

CONCLUSIONS

The CDIO Initiative offers the tools to develop the curriculum of the Engineering Biology program at Linköping University. It is obvious that the concept can be used in non-traditional engineering areas where the “product” is somewhat different compared to electrical and mechanical engineering. The Engineering Biology program redesigning process has involved many members of the teaching staff and the collaborations between different departments and even faculties has increased markedly. Some of the skills asked for by the alumni and stakeholders can be brought to students an increasingly realistic way.

ACKNOWLEDGEMENTS

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